AN EIGHT-YEAR CYCLE IN RAINFALL.

By HENRY LUDWELL MOORE.

[Columbia University, August 4, 1922.]

The table on *Rainfall departures, United States (as a unit)* that appeared in an article by Prof. A. J. Henry in the March number of this REVIEW [1] supplies invaluable data for the theory of rainfall cycles. In Table 1 Professor Henry's figures relating to the smoothed rainfall departures are tabulated. The method of smoothing the data that was followed by Professor Henry is given by "the formula $b = \frac{1}{4}(a + 2b + c)$ where b is the middle year in any consecutive series of three years."

TABLE 1.—*Rainfall departures, United States (as a unit).*

Years.	Smoothed departures.	Years.	Smoothed departures.
1881	+0.4	1901	−2.1
1882	+0.2	1902	−2.0
1883	±0.0	1903	−2.5
1884	+0.4	1904	−2.6
1885	−0.4	1905	−1.0
1886	−2.7	1906	−0.4
1887	−3.2	1907	−1.6
1888	−2.1	1908	−1.8
1889	−2.0	1909	−2.4
1890	−2.4	1910	−3.8
1891	−1.3	1911	−2.6
1892	−2.5	1912	−1.1
1893	−3.1	1913	−1.8
1894	−3.5	1914	−1.9
1895	−3.2	1915	−1.5
1896	−2.1	1916	−3.2
1897	−1.6	1917	−4.7
1898	−2.1	1918	−3.4
1899	−2.2	1919	−1.5
1900	−2.0	1920	−0.9

In Figure 1 the smoothed departures are plotted together with a graph of an eight-year cycle that was derived from the smoothed departures by the Method of Least Squares. The substantial agreement of the computed cycles with Professor Henry's smoothed departures *saute aux yeux*.

According to the equation of the computed cycles the theoretical maxima occurred at about 1882, 1890, 1898, 1906, 1914, and I was about to add 1922, so nearly certain does it seem that the present year will be characterized by an unusually large rainfall. In other places [2] I have shown that eight-year cycles with approximately these same dates for maxima occur in the rainfall of the Ohio Valley, the rainfall of Illinois, the May and June rainfall of the Dakotas, the barometric pressure in the United States, the winter barometric pressure in Central Europe,

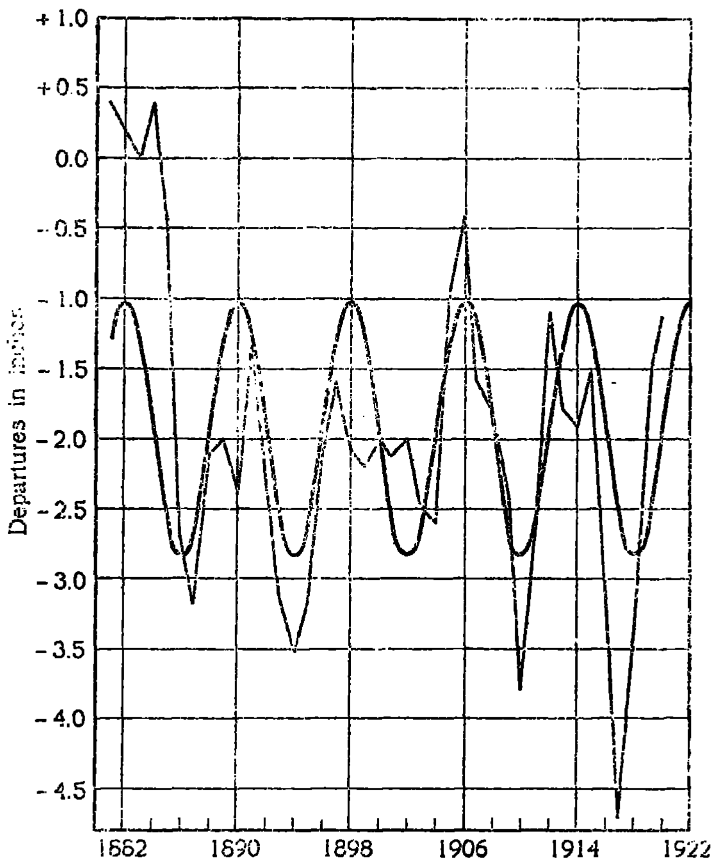

FIG. 1.—Smoothed departures of rainfall in the United States (as a unit). Equation to the eight-year cycle: $y = -1.95 + 0.90 \sin (45°t + 45°37')$, origin at 1881.

the yield of crops in the United States, the yield of crops in the United Kingdom, the yield of crops in France, and the index number of general wholesale prices throughout a century.

[1] MO. WEATHER REV., March, 1922, p. 130.
[2] Particularly "The Origin of the Eight-Year Generating Cycle." *Quarterly Journal of Economics*, November, 1921.

BROOKS AND GLASSPOOLE ON THE DROUGHT OF 1921.[1]

By A. J. HENRY.

The first section of this paper is devoted to a discussion of the 1921 and other dry periods in the British Isles. The second section takes up the causes of droughts and it is with this section that readers of the REVIEW will be particularly interested.

It is recognized that the establishment and maintenance of local anticyclonic conditions is closely associated with dry weather; the immediate concern, therefore, is to discover, if practicable, how the local abnormalities of pressure distribution are related to others in the general circulation in different parts of the world.

Charts were constructed showing the deviation of pressure from the normal over a considerable portion of the Northern Hemisphere for the 1921 and other severe droughts. The periods are as follows:

April to August, 1864.
May to July, 1868.
October to January, 1880.
February to October, 1887.
March to June, 1893.
February to June 1895.
January to May, 1896.
July to October, 1911.
February to October, 1921.

The pressure distribution for the above periods fell clearly into two types which were designated the A and the B types. The A type, however, comprised but two droughts—February to June, 1895, and August to October, 1911. This type is characterized by high pressure to the north of the British Isles. The Icelandic minimum is shifted toward West Greenland and the Azores maximum is feebly developed. In this case

[1] C. E. P. Brooks and J. Glasspoole: The Drought of 1921, *Quart. Jour. XLVII*, p. 139-166.

the drought is said to be due to dry winds rather than to anticyclonic conditions. Depressions were few and either passed to the south across the Bay of Biscay or descended from the Arctic Ocean southward or southeastward across Scandinavia.

Type B, which includes the remainder of the examples, is characterized by a region of maximum positive pressure abnormality centered directly over the British Isles amounting to 4 mb. (0.12 inch) at the central portion.

Combining all of the cases except 1895 and 1911 into a single chart the result is shown in a chart of mean pressure deviation as in Figure 1.

This chart shows that the pressure abnormality decreases from a maximum over the British Isles both to the north and to the south. Pressure is below the normal over the Arctic Ocean and at the Azores. In terms of the so-called centers of action it may be said the Azores maximum is shifted to the northeast and concurrently the Icelandic minimum is also shifted to the northeast. These two movements are closely related. Exner has found definite negative correlations between polar pressures and corresponding pressures over western and southern Europe.

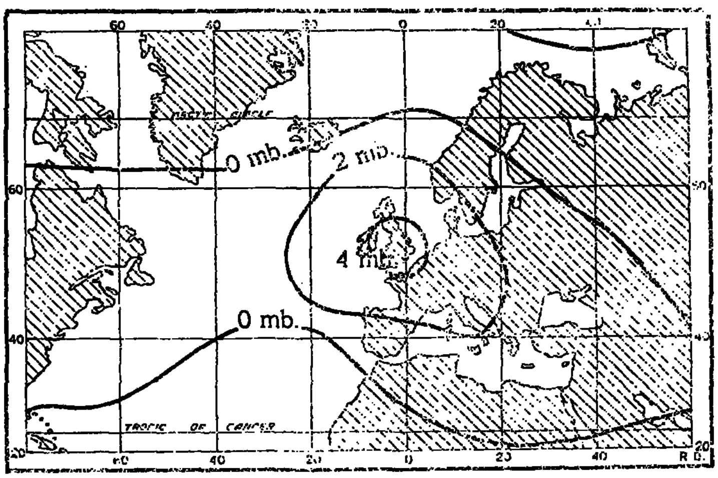

FIG. 1.—Chart of pressure deviation: mean of seven droughts.

It is evident, therefore, that high pressure in the Temperate Zone is closely associated with low pressure near the poles, at least in winter. In order to examine the question more closely, the authors next correlated the pressure at Valencia with corresponding pressures at Stykkisholm, Berlin, Ponta Delgada, and Vardo with the result that Vardo is definitely opposed to Valencia in all seasons except summer, when it apparently lies between the European and the Arctic régimes. In this season the Arctic center lies farther north, for, taking the 12 years which are unfortunately all that are available for Spitsbergen the authors get a correlation with Valencia of −0.78 in summer. Further, when they calculate from the above coefficients and the standard deviations the difference from normal corresponding to 4 mb. at Valencia they find good agreement with the results shown in Figure 1. This indicates that drought conditions are not isolated phenomena but are merely the extreme cases in one direction of the usual variations to which the pressure distribution, and therefore the atmospheric circulation, is liable.

The cause of drought in the British Isles must, therefore, be looked for in some variation in the strength of the atmospheric circulation. As between the polar regions and the Tropics the former is the better of the two as an indicator of a change in the temperature gradient and naturally a corresponding change in the strength of the circulation.

The authors show that low pressure in the polar regions is associated with droughts of Type B. Low pressure in those regions is associated with great storminess and high temperature. The dearth of meteorological stations in the Arctic makes it impossible to confirm this statement by the usual statistical methods; the belief is expressed, however, that warm weather in the Arctic Ocean is associated with, and perhaps causes, a more northerly position of the subtropical anticyclones and, consequently, high pressure over the British Isles.

The relation of droughts to the sunspot cycle, variation in the amount and position of Arctic ice, and the periodic movement of the Icelandic minimum are next discussed in separate paragraphs.

With reference to the sunspot relation it is pointed out that according to Fisher [2] a few years (1 to 4½) after sunspot maximum the Azores anticyclone tends to extend northward over Spain and the Bay of Biscay or even over the British Isles.

Droughts are accordingly most frequent at this stage of the cycle (4 years after spot maximum). The data of droughts are, however, so spread over the cycle that the result is not of great value.

A movement of the Icelandic minimum having a period of 8 months, and another having a period of 4.8 years, is distinguished. Accounts as to the interaction of the Icelandic minimum and the surface temperature of the North Atlantic are due to several investigators. W. Meinardus and J. Petersen are quoted specifically. According to them, when the Icelandic minimum lies to the westward of its normal position, say over West Greenland, the southwest winds between Iceland and northwest Europe will be unusually strong and steady. These warm winds will raise the temperature of the surface waters both by their own high temperature and by strengthening the Gulf Drift. This warm water after a time draws the Icelandic minimum eastward and also causes it to become more intense, which still further increases the temperature and velocity of the Gulf Drift. But it also increases the cold currents, especially the Labrador Current, and cools the Gulf Drift and, after the necessary time, this cools the northern seas and induces a fall of temperature over the Northeastern Atlantic, so that pressure rises again there and the Icelandic minimum retreats westward becoming less intense at the same time.

This hypothesis was tested by the Reseau Mondial charts of pressure deviation for the years 1910–1915 and was found to represent the facts shown there very accurately.

The short period movements of the Icelandic minimum from 1910 to 1915 are shown in the statement below:

MINIMUM TO WESTWARD.	MINIMUM TO EASTWARD.
August to October, 1910.	January to July, 1910.
January to May, 1911.	November to December, 1910.
July to November, 1911.	June, 1911.
April to May, 1912.	December, 1911, to March, 1912.
October to November, 1912.	June to September, 1912.
February, 1913.	December, 1912, to January, 1913.
June to September, 1913.	March to May, 1913.
July to November, 1914.	October, 1913, to June, 1914.
October, 1915.	December, 1914 to April, 1915.
	November to December, 1915.

[2] Das Wetter, 1916, p. 232.

Examination of the Reseau Mondial charts suggests that there is also a northeast-southwest oscillation of the Icelandic minimum ranging from Spitsbergen or northern Russia to Newfoundland, which takes place much more slowly. Since the greatest droughts occur when this minimum is not to the west over Greenland but unusually far north toward Spitzbergen, this longer oscillation is discussed at some length. There is strong reason the authors assert for supposing that this northeast-southwest oscillation of the Icelandic minimum is connected with the ice conditions in the Arctic waters, for droughts of Type B in the British Isles are followed by years with much ice near Iceland.

The sequence of events leading up to a drought in the British Isles with low pressure in the neighborhood of Spitzbergen is about as follows: In the Arctic Ocean the temperature is abnormally high and the weather is stormy. Consequently, the polar ice is broken up and much floe and field ice drifts into the East Greenland current. Owing to the prevalence of strong westerly winds this ice is spread out to the eastward of its normal limits and some of it collects around the shores of Iceland. Between Spitzbergen and Iceland the average velocity of the ice is about 7 miles a day, so that it would take some 200 days, or nearly 7 months, on the journey, and the ice broken up in summer would appear off Iceland early in the following year. The Arctic ice generally passes Cape Farewell in January or February. It follows the southerly current up the west coast of Greenland nearly as far as Disko Island, 70° north. Here it is driven westward by the easterly winds of spring, after which it again drifts southward along the western side of Baffin Bay and Davis Strait into the Labrador Current, which carries it past Newfoundland into the Gulf Drift.

As the floating ice melts it must cause an appreciable cooling and this cooling is propagated to the northeastward with the velocity of the current and it finally reaches the Northeastern Atlantic. The deficit in temperature of the Gulf Drift is followed by a cold season in the Arctic Ocean with high pressure and an absence of storminess. Hence there is little loose ice to be swept into the East Greenland current and the whole sequence begins again, but with the values reversed.

The total length of this path of circulation is about 7,000 miles and the average velocity of the current is about 8 miles a day. This gives a period of 2.4 years for a change from warm to cold conditions in the Arctic, or 4.8 years for the complete cycle, which exactly coincide with the periodicity of ice conditions off Iceland as demonstrated by Meinardus.[3]

In regard to forecasting droughts the authors say:

> If pressure becomes persistently low over the Arctic regions, especially at Spitzbergen, the possibility of an approaching drought must be considered. If pressure is also low over the Tropics the chances are somewhat greater, especially if the position in the 11-year solar cycle is favorable and 4 years have elapsed since the last drought. If under these conditions pressure becomes high over the Urals or northern Russia, it appears highly probable that a drought will set in within the next few months. Unfortunately the last source of information is still closed to us.
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> The conclusions reached in this paper require to be verified and extended by a similar study of exceptionally rainy periods.

DISCUSSION.

In the discussion that followed, Dr. G. C. Simpson made the interesting suggestion that an increase in the velocity of the whirl about the poles would result in a fall in pressure in the center and a rise on the margins. Thus, when the vortex in the atmosphere in the northern regions becomes intensified, the pressure in the polar regions is decreased while that in the surrounding belt is increased. This causes the Azores high pressure to move farther north and the movement of this high pressure alters the whole of the climatic conditions of England.

Doctor Simpson also remarked that the place to look for forecasts and the mechanism of the whole thing was in the upper atmosphere where the whirl is to be found. He also remarked that probably it would be found that the pressure changes are not localized in that part of the world in which the rainfall shows the greatest abnormalities.

[3] Ann. Hydrogr. Berlin, 34, 1906, pp. 148, 227, 278.

BRIEF DESCRIPTION OF A NEW DIAL FOR THE ANEROID.

By JOSÉ CARLOS MILLÁS, Director.

[Observatorio Nacional, Habana, Cuba, June 20, 1922.]

Facing always the difficulties of obtaining good observations from untrained observers, the idea of changing the usual dial of the aneroid barometer for a simpler one, such as could be read without trouble and without training, presented itself as a solution to the problem constantly encountered by the Observatorio Nacional of Cuba.

When a meteorological service has to depend on observations made by nontechnical observers, the greatest pains should be taken to insure accuracy with *the least possible* labor to the observer. Our experience of many years in receiving daily telegrams from such a class of observers compelled us to use the aneroid with the new dial.

The instrument for this purpose should be a good aneroid, with as large a dial as possible. All division lines are absent. Instead, a system of short words is inserted, say for every millimeter of pressure. In our instruments the circle described by the index hand is about 5 inches in diameter. The words were not well placed by the printer, as those dials were printed on bristol board; therefore, we had to determine the exact value of the space from word to word. (See fig. 1.)

These short words are so chosen that no confusion whatever is possible in the telegraphic transmission of the message. The observer sends the word nearest to the index or, if it falls between two words, both are sent at the same time as one word. In this manner, the instrument reads to half a millimeter (0.02 inch). Before reading, the observer should tap the instrument lightly. In our dials we place a sign that says: *Golpear el cristal antes de leer;* the observer on facing the instrument reads that the glass should be tapped lightly before reading, *a most necessary operation* with this class of instruments. This is the only weak point of the barometer, as the observer may forget to tap it lightly before reading. To avoid this, the instrument could be placed in a case with a small door, and a mechanism attached to it so that the instrument would be tapped mechanically by the opening of the door. Then the only thing the observer would have to do would be to read the word or words.

We take away the hand-moved index that usually accompanies this class of barometers; it is not needed and may introduce errors. The correction screw is covered so as to make the barometer foolproof.